

Digital Twins: A Survey on Enabling Technologies, Challenges, Trends and Future Prospects

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Abstract

Digital Twin (DT) is an emerging technology surrounded by many promises, and potentials to reshape the future of industries and society overall. A DT is a system-of-systems which goes far beyond the traditional computer-based simulations and analysis. It is a replication of all the elements, processes, dynamics, and firmware of a physical system into a digital counterpart. The two systems (physical and digital) exist side by side, sharing all the inputs and operations using real-time data communications and information transfer. With the incorporation of Internet of Things (IoT), Artificial Intelligence (AI), 3D models, next generation mobile communications (5G/6G), Augmented Reality (AR), Virtual Reality (VR), distributed computing, Transfer Learning (TL), and electronic sensors, the digital/virtual counterpart of the real-world system is able to provide seamless monitoring, analysis, evaluation and predictions. The DT offers a platform for the testing and analysing of complex systems, which would be impossible in traditional simulations and modular evaluations. However, the development of this technology faces many challenges including the complexities in effective communication and data accumulation, data unavailability to train Machine Learning (ML) models, lack of processing power to support high fidelity twins, the high need for interdisciplinary collaboration, and the absence of standardized development methodologies and validation measures. Being in the early stages of development, DTs lack sufficient documentation. In this context, this survey paper aims to cover the important aspects in realization of the technology. The key enabling technologies, challenges and prospects of DTs are highlighted. The paper provides a deep insight into the technology, lists design goals and objectives, highlights design challenges and limitations across industries, discusses research and commercial developments, provides its applications and use cases, offers case studies in industry, infrastructure and healthcare, lists main service providers and stakeholders, and covers developments to date, as well as viable research dimensions for future developments in DTs.